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ABSTRACT

The Prince George's County (Maryland) school system has developed a database warehouse system as an evaluation data support tool for fulfilling the system's information demands. This paper described the Research and Evaluation Assimilation Database (READ) warehouse support system and considers the requirements for data used in evaluation and how data can be prepared to meet these requirements. Evaluation data must identify and characterize the program or practice under examination. However, the proactive data collection features of warehousing data require that enough of the right kind of data be collected before any evaluation study proposal. READ's wealth of legacy data, data quality control procedures, and data management functions facilitate the school district's capacity to reach objective evaluation results. The READ data collection scheme focuses on five core database entities: student, teacher, school, program, and instructional finance. Metadata, or "data about data," is a built-in component of the system. The READ system also uses a four-stage data processing approach of: (1) collection and confirmation; (2) scrubbing and enhancement; (3) structure and storage; and (4) analysis and reporting. Scrubbing includes standardizing the naming syntax, formats, and values associated with incoming data elements. This is an essential component of preparing the data for evaluation use. The Table of Contents for the READ "Technical Manual" is attached as an outline of the detailed descriptions and definitions in the manual. (Contains five figures.) (SLD)

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School District Evaluation: Database Warehouse Support

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Research, Evaluation and Accountability
Prince George's County Public Schools

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School District Evaluation: Database Warehouse Support[1]

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Educational decision-making relies upon evaluation as the only way to make rational choices between alternative practices, to validate educational improvements, and to build a stable foundation of effective practices as a safeguard against faddish but ineffective innovations. Additionally, policies of private and government agencies currently make approval of systemic reform programs, new educational initiatives, and research grants contingent upon evidence of good planning and sound evaluation procedures. Consequently, local school districts are looking for ways to upgrade their evaluation support systems in the face of increasingly complex data environments and more stringent demands for higher quality evaluation reporting.

The overall problem is that quality decision making requires uniform, timely, and accurate educational information. The practical problem is to provide successful assimilation of many years of accumulated, complex and ambiguous data from a wide variety of sources, optimize the data into reliable and meaningful data elements, and structure the data for optimal control, management, query and extraction. The solution is to upgrade school district evaluation offices with relational database capabilities, to establish a database warehouse support system for evaluation and research, and to support this system with access to all pertinent data sources within the district. The need to have a ready pool of reliable and valid data to support school district multiple evaluation needs can be solved through the institutionalization of the same new data warehouse technology currently being developed and applied to a variety of successful commercial enterprises.

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[1] Paper presented at the Summer Data Conference, National Center for Education Statistics, The U.S. Department of Education, Office of Educational Research and Improvement, Washington D.C., July 24-26, 1996.

From the perspective of staff responsible for fulfilling the evaluation needs of a large public school system, this paper presents an inside look at our current evaluation experience and how a database warehouse system has been developed as an indispensable evaluation data support tool for fulfilling the information demands of contemporary public school systems. Particular attention is given to an often overlooked, but critical evaluation issue: What are the requirements for data used in evaluation, and how can data be prepared to meet these requirements? Also, an overview of the design and operational characteristics of the *Research and Evaluation Assimilation Database* (READ) warehouse support system for evaluation activities in the Prince George's County Public Schools (PGCPS) system is presented.

The School District of the 1990's

The 1990's have been characterized by rapidly changing school environments, reform programs and systemic initiatives. In such an environment, public school evaluation offices can no longer wait until questions arrive to begin gathering pertinent evaluation data. The increasing public demand to hold schools accountable for their impact on student outcomes lends urgency to the task of establishing an evaluation response system with a pool of available data for statistical information processing. Also, the quality of reported results characterized by the historical practice of providing simple data aggregation and profile information often falls short of the objectives and unambiguous results now required by decision makers. Instead, the quality of evaluation results desired and expected comes from a process which arranges data on the basis of scientific design methodology and analyzes data using appropriate statistical procedures.

The authors of this paper contend that the modern evaluation office needs to add the evaluation data support capabilities of a relational database warehouse system to its office infrastructure. We have applied modern data warehouse system technology that has been

developed by computer scientists William Inmon[2] and Richard Hackathorn[3] to capture, manage, and use the rich supply of years of accumulated school district data for research and evaluation purposes. In the four stage READ data warehouse pipeline, we have successfully adapted this business oriented technology to the public school environment. The evaluation data support provided by the READ warehousing system provides an indispensable, ready supply of accurate and reliable data that improves the overall efficiency and effectiveness of the evaluation office in a very demanding public school environment.

Figure 1 presents the database warehouse evaluation support structure that has been developed in the Research, Evaluation and Accountability (REA) office of the Prince George's County Public Schools (PGCPS). Within this evaluation structure, the READ warehousing support serves as the legacy[4] data capturing agent, data scrubbing and enhancement agent, and the evaluation data delivery agent to the statistical analysis stage of the evaluation office. These READ services have developed into such an indispensable evaluation support tool that it has effectively reshaped the entire infrastructure and operational characteristics of the evaluation office.

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2 Inmon, William H., Building the Data Warehouse, Wiley-QED, NY, 1992.

3 Inmon, W. H., & Hackathorn, R., Using the Data Warehouse, Wiley-QED, NY, 1994.

4 A legacy system is an established online transaction processing system that serves a specific management purpose within an enterprise. Typical school system legacy systems include payroll, personnel, instructional data systems (processes student course schedules and report cards), and pupil accounting and school boundaries (processes student-school enrollment status and attendance).

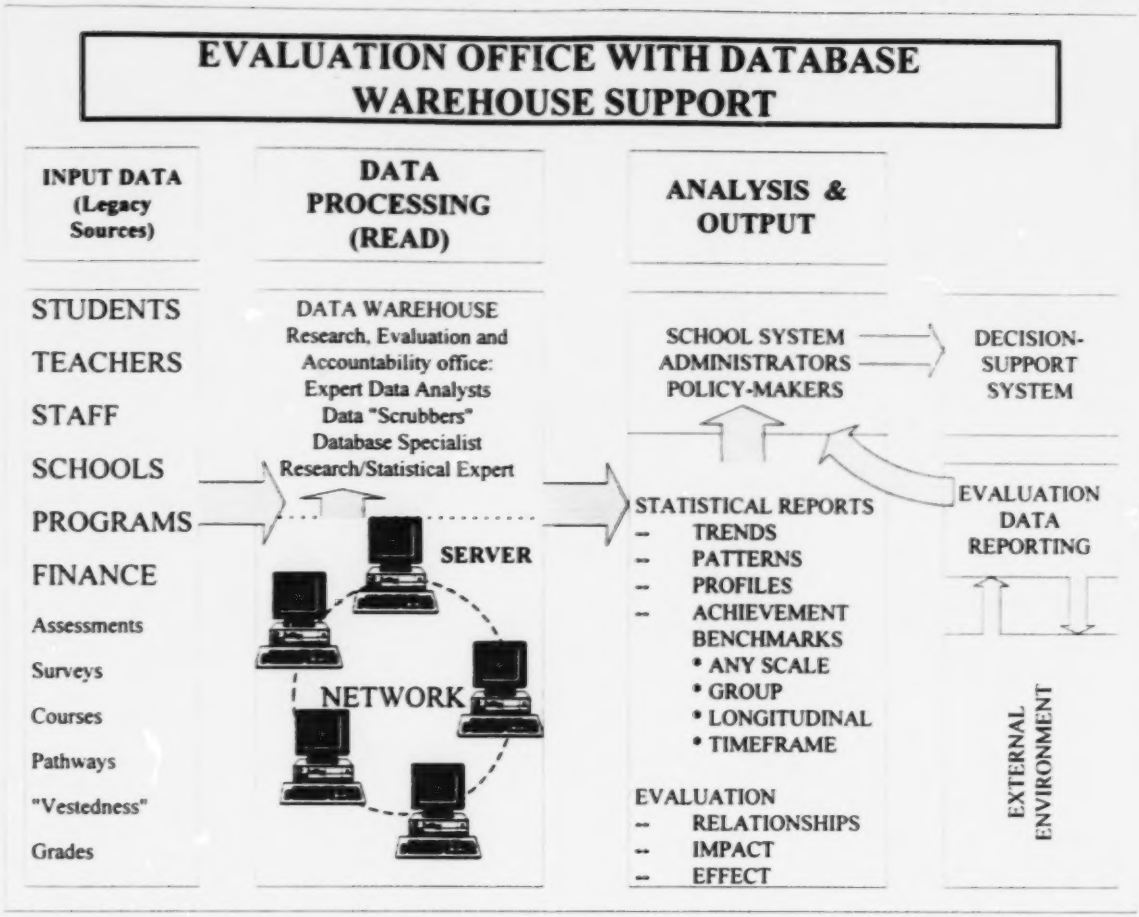

Figure 1: **READ-Based Evaluation Office Model**

READ Evaluation Data Requirements

In 1981, a Joint Committee issued one of the most significant documents to date in the field of educational evaluation entitled *Standards for Evaluation of Educational Programs, Projects, and Materials*.[5] It consisted of a set of 30 standards to be used both to guide the

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[5] *Standards for Evaluations of Educational Programs, Projects, and Materials*. Developed by the Joint Committee on Standards for Educational Evaluation, McGraw-Hill, 1981.

conduct of evaluation of educational programs, projects, and practices and also to judge the soundness of such evaluations. The 30 standards are grouped according to four attributes of an evaluation -- its utility, its feasibility, its propriety, and its accuracy. The evaluation accuracy standards, in particular, served as our guide in the development of the READ data gathering and quality control activities.

The requirement standards for evaluation data require that the information obtained be technically adequate and linked logically to the evaluation objectives. Technical specifications for adequate evaluation data usually exceed those used by the legacy data sources from which REA collects raw data. Quality assurance is given such importance that the READ data warehousing pipeline has dedicated substantial resources to data verification, documentation, scrubbing and enhancement activities.

According to the *Standards*, evaluation data must clearly identify and characterize the program or practice under examination (independent, dependent, and treatment data), and embody the contextual characteristics of the program under examination (e.g., size, scope, and time). The proactive data collection features of data warehousing, however, require that enough of the right kind of data be collected prior to any evaluation study proposal. Thus, a data collection scheme, based upon the most commonly required educational evaluation contextual and educational practice variables had to be devised for the READ data warehousing system. This READ data collection scheme focuses on the following **five core database entities**: student, teacher, school, program and instructional finance. These core database entities and the total database structure is presented in detail in the READ Technical Manual.

Metadata, or "data about data" is a built-in component of the READ warehousing system. The metadata component fulfills the following quality assurance provision of the *Standard:* "The sources of information should be described in enough detail so that the adequacy of the information can be assessed." Metadata is a particularly useful quality control component when it comes to using previous year data to perform *post-hoc* evaluation studies or trend analyses.

Storing information about the legacy sources of data as READ metadata provides another important management tool for this evaluation support system.

Experience has taught the READ staff that there is often a considerable gap in the quality requirements for evaluation data and the condition of raw data received from legacy sources. Still, the *Standards'* requirement for systematic data control state that: "The data collected, processed, and reported in an evaluation should be reviewed and corrected, so that the results of the evaluation will not be flawed." (*Standards (1981)*, D7: Systematic Data Control, emphasis added). Thus, the READ system has devised sophisticated data scrubbing procedures which examine both the physical and statistical characteristics of data in order to ensure that evaluation data quality standards are being met. The next section presents an overview of the four stage READ system with a particular emphasis on preparing school system data for evaluation use.

READ Function and Flow

On the local school district level, the purpose of the Research and Evaluation Assimilation Database (READ) is to fulfill the input data requirements for the evaluation design and statistical analysis operations of the Research, Evaluation and Accountability (REA) office of the Prince George's County Public Schools (PGCPS) system. The REA mission is to provide fair and scientifically valid approaches to the evaluation of school and program effects. REA fulfills the school district's evaluation needs through the development of the READ warehousing system which is a proactive "end-to-end" evaluation system with four major data processing phases: 1) collect and confirm; 2) "scrub" and enhance; 3) structure and store; and 4) analyze and report. Figure 2 shows the four stage evaluation support system which characterizes READ.

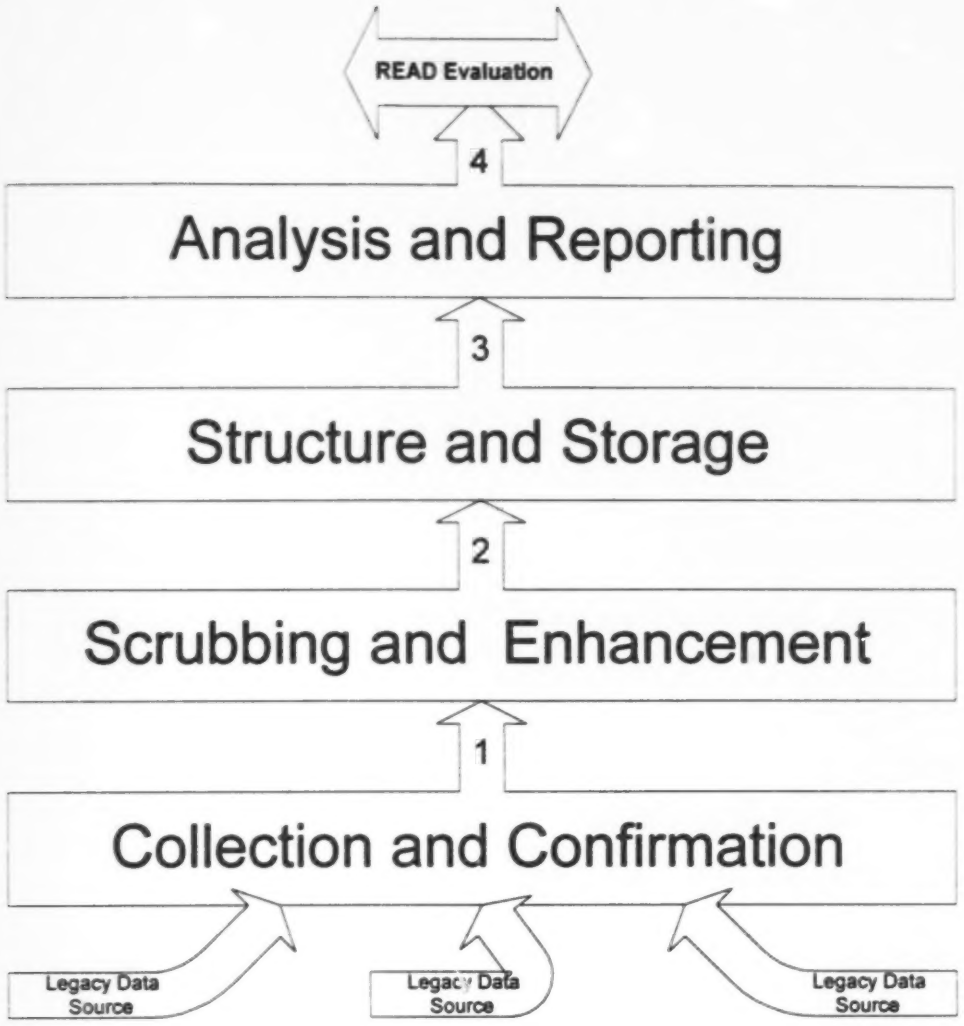

Figure 2: **READ Four Stage Pipeline Processing System**

One way to visualize how school system data flows through the READ data warehouse pipeline is to see how data is "pulled" from station to station in response to detailed control specifications. That is, the evaluation process "works in reverse," from an evaluation question backwards to a pool of proactively captured and prepared data. The system design "pull" of

READ-based evaluation data begins with the decision support needs stipulated at stage four ("Analysis and Reporting") which, in turn extracts data from stage three ("Structure and Storage") which has prepared data received from stage two ("Scrubbing and Enhancement"), that was initially acquired from the various legacy data stores of the school district in the first stage ("Collection and Confirmation"). Thus, the function of the READ system is established by the decision support evaluation concerns of the school district and NOT the Management Information System (MIS) department.

Preparing School System Data for Evaluation Use

Quality assurance activities occur at each data transition point along the four stages of the READ data pipeline shown in Figure 2. The control specifications detail the file, record and data element parameters of the receiving station. The READ Technical Manual provides examples of different types of control specification request forms used by the REA staff at each READ pipeline station (e.g., "Data Request Form," "Data Transfer Form," and "Record Specification Form"). The type and specificity of the form used to control the data transfer depends upon the point in the pipeline where data is being transferred. The "Record Specification Form" used to build a Sufficient Statistics Matrix (SSM)[6] file for hierarchical linear modeling school effects evaluation, for example, is very specific and exacting because it requires "drilling across" several READ tables. Extracting an SSM file requires expert relational database skills and specific knowledge of the data warehouse structure and content. Also, an SSM file extraction undergoes the highest level of quality assurance processing before any analysis at READ station four ("Analysis & Reporting").

Figure 3 graphically shows the multi-step procedure used to build an SSM file from value-added, student-centric data warehouse data. The researcher makes an SSM file request based upon the evaluation needs of scientific design methodology and the statistical analysis

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[6] Sufficient Statistics Matrix is an efficiently assimilated input data file for statistical analysis. An SSM is constructed to meet the scientific design requirements to address the evaluation question and possess the quality characteristics to yield reliable results. The term SSM is borrowed, and adapted, from Bryk, Raudenbush, and Congdon (SSI) 1996.

quality conditions necessary to empirically address a decision support situation. The ability to readily extract an SSM file from the READ warehouse represents the most important function of the READ database support system.

Processing to Build Evaluation Data for a Sufficient Statistical Matrix (SSM) File

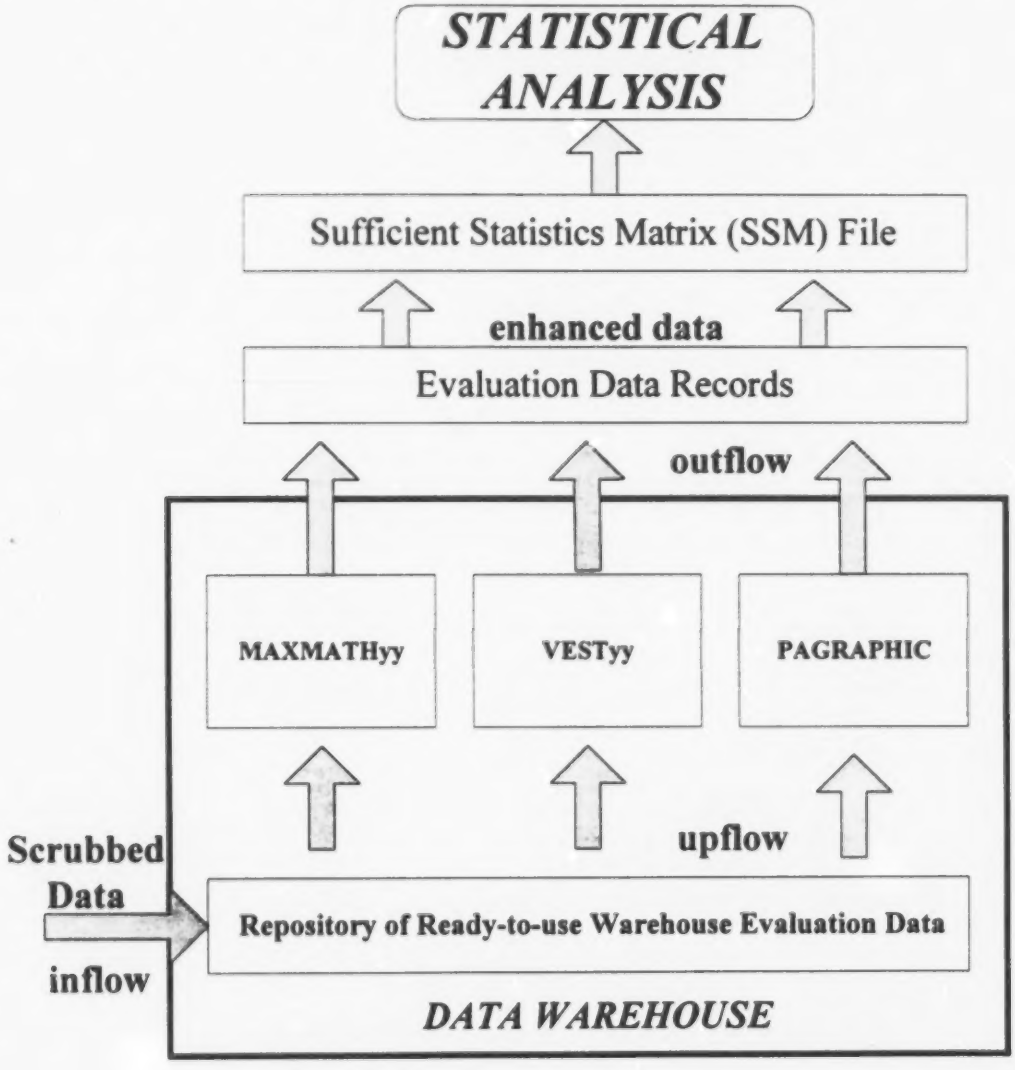

Figure 3: **READ Model For Building Evaluation Data**

Figure 3 shows the READ system data flow from pipeline stage two ("Scrubbed Data"), to stage three ("Data Warehouse"), and on to stage four ("Statistical Analysis") with particular emphasis on the structuring procedures used to build an SSM file for evaluation analysis. New scrubbed and formatted data arrives at the data warehouse as an "inflow" process. Storage in the data warehouse requires reformatting and partitioning of data into subject oriented database tables, such as course tables, enrollment history, and student characteristics. In the example provided in Figure 3, evaluation data records are constructed for analysis of the relationship between student demographic characteristics, student enrollment history and student mathematics course achievement. That is, an SSM file is constructed from evaluation records which assimilate scrubbed, structured, and stored data by "drilling across" the following summarized and partitioned subject tables: pupil accounting student demographic table (PAGRAPHIC), student "vested" enrollment history table (VESTyy), and student mathematics course matriculation history table (MAXMATHyy). This simple example can be expanded as necessary in response to particular needs for any decision support evaluation. Again, it is this capability to produce proactively prepared evaluation data on demand that is the most important contribution of database warehouse technology to evaluation decision support operations.

READ warehouse pipeline procedures require data scrubbing for all incoming data. Scrubbing data to evaluation requirement specifications often involves enhancement or "value added" processing and summarization of newly acquired legacy data, and the analysis and reporting responsibilities of the REA office require the highest degree of quality assurance and quality control of data extracted from READ. Data "scrubbing" is the second data management stage in the READ pipeline. During this scrubbing stage data undergoes initial standardization, normalization and enhancement (or "value adding") in preparation for uploading to READ databases. Data scrubbing includes standardizing the naming syntax, formats, and values associated with incoming data elements.

Experience has taught READ staff that because of the interconnected structure of a data warehouse environment, mistakes in naming syntax cost dearly in staff time to root out and

correct. Other data enhancement activities include recoding data element values or rearranging the existing data values into a well-defined structure, computing new data elements, or adding categorical "flags" to an incoming data element. Data enhancement is a vital, proactive data preparation phase for the READ system operations and greatly facilitates the REA office capabilities to provide quick responses to evaluation questions. The scrubbed and enhanced data is pulled or uploaded into pre-designed READ database tables at station three ("Structure and Storage"). The control specifications for pulling the data into these READ tables come from the tables' structural design (e.g., data element specifications and characteristics). Data is partitioned into subject specific, normalized tables based on category (e.g., courses, tests, demographics, enrollment, etc.) and then summarized to meet evaluation data requirements for future statistical analysis purposes. As a final step, elements in the READ data tables are defined and documented (i.e., metadata) for later retrieval and analysis use. Thus, quality assurance occurs at all phases of the READ data pipeline process: data collection and confirmation, data scrubbing and enhancement, data storage and structure, and data analysis and reporting.

READ Form and Design

Evaluation concerns also drive the form of the database entities which make up the READ warehouse support system. The READ system data warehouse is designed and maintained to accommodate the evaluation data requirements of decision makers' questions that will be asked some time in the future. This proactive engineering requires the expert perspective of experienced evaluation staff familiar with the evaluation demands of public school systems. A particularly critical engineering ingredient is the operational definitions for the database entities, subentities, elements, and values which database staff use to build and manage the READ system. The form, or logical view of the READ system, as currently configured, is pictured in the student-centric entity "wheel" displayed in Figure 4.

While the actual database infrastructure is substantively more complex, the "wheel' relationship depicts the links between tables and data elements within READ. The relationship wheel presents the core evaluation entities used to link the most important input, practices,

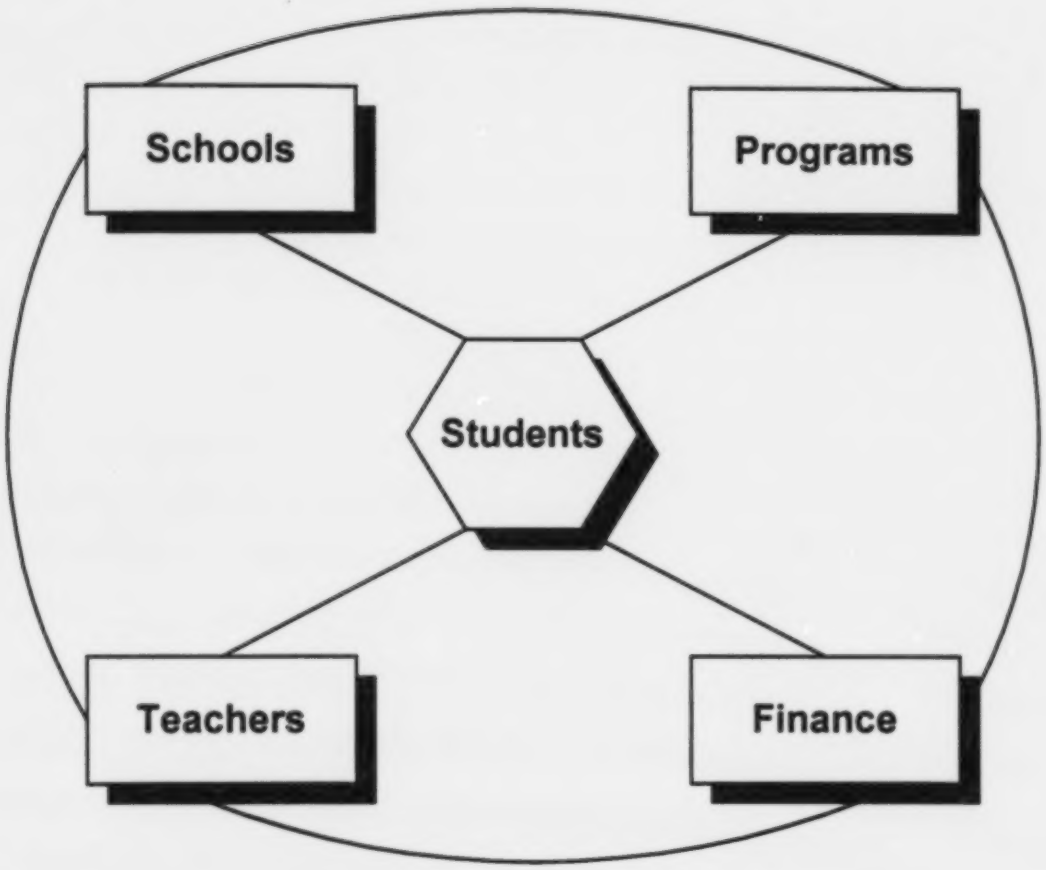

Figure 4: **READ Student-Centric Entity Relationship:** ***Logical View***

programs, and outcomes of the school district. The circular or "wheel" links and the spoke or "star" links displayed in Figure 4 show the established (and desired) database relationships between the READ entities. Currently, the data entities on the "wheel" are linked either directly at the student level (e.g., schools are linked to individual students) or indirectly to the student level (i.e., between the entities themselves, for example, core teachers at the elementary school level are linked to schools at the elementary school level and courses at the secondary level). The goal of the database staff is to fully develop the direct links between individual student records and those of the other core entities (i.e., the wheel's "spokes"). For example, staff are

currently working on one data project that will establish a direct link between all students and their core subject teachers (i.e., mathematics, science, social studies and language), and another data project to link all students to a financial index table representing the cost associated with the delivery of core subject instruction. In terms of evaluation support, directly linking all entity data at the student level will provide the most robust evaluation design possibilities as input, practice, and outcome factors can be arranged at the student level of analysis.

A simplified Entity-Relationship Diagram (ERD) of a portion of the READ data system is presented in Figure 5. An Entity-Relationship Diagram is the traditional development tool

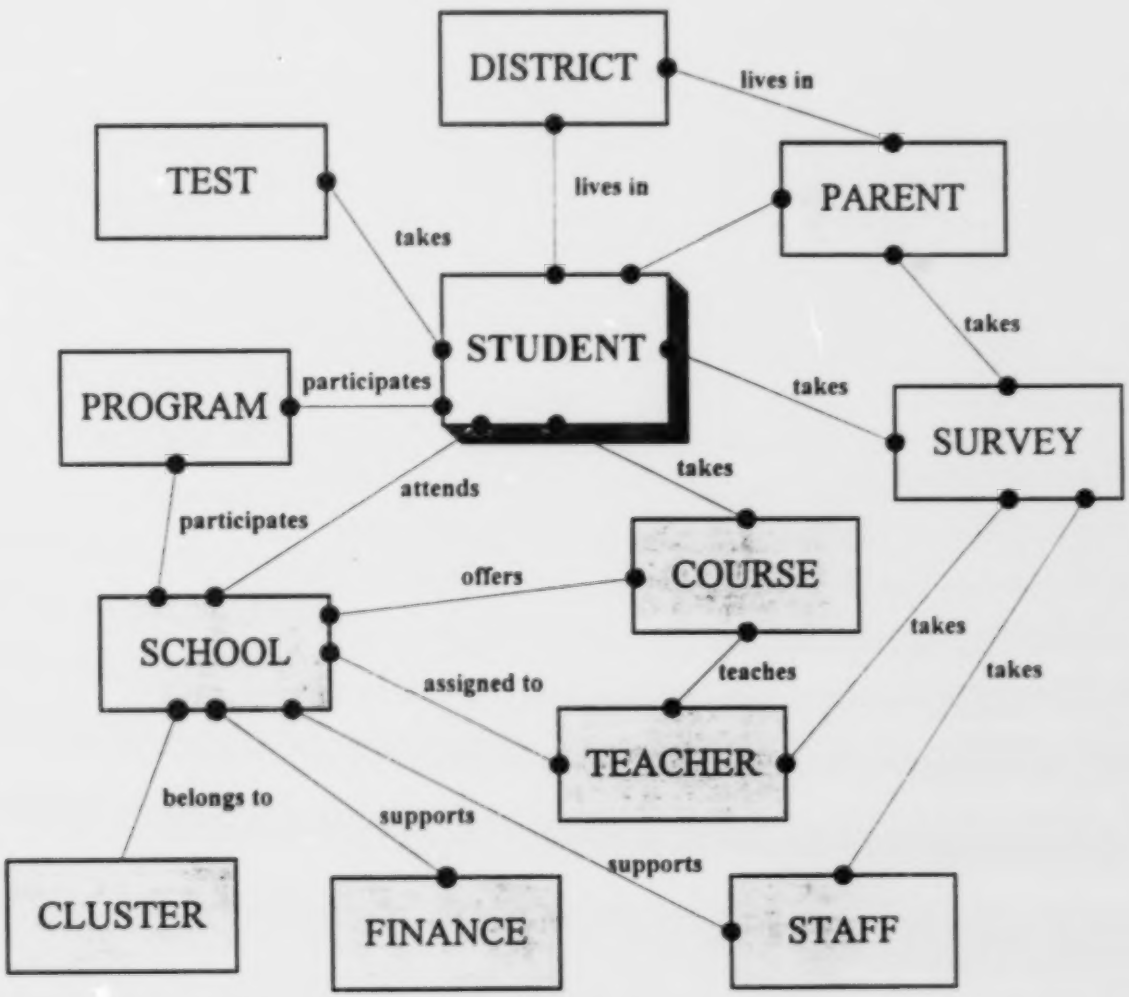

Figure 5: **READ Entity-Relationship Diagram**

used to facilitate the logical design phase of a database system. An ERD provides a clear representation of all the data elements (i.e., "entities") and their linking relationships. Entities then evolve into relational database tables as part of the physical design phase. As Figure 5 shows, not all core entities are directly linked to students in the current design (e.g., TEACHER is linked to COURSE but not directly to STUDENT). The database design goal is to complete the student-centric form of READ by building the direct relationship links between the STUDENT entity and the other core entities.

The READ Technical Manual

A detailed description of the READ entity, element and value operational definitions is beyond the scope of this paper. This information is contained in the READ Technical Manual (RTM). The first edition of the RTM has been completed in July 1996. The RTM is a comprehensive description of the evaluation support database, infrastructure, and procedures used by the Research, Evaluation and Accountability (REA) staff in the Prince George's County Public Schools (PGCPS) district to perform evaluation studies. This manual captures every aspect of the READ System since its inception three years ago. The justification for developing a data warehouse for public school program evaluation is discussed. The importance of proactive data collection from district legacy data sources is covered in detail, followed by a description of the procedures used to integrate historical data in different formats using relational database technology. The importance and magnitude of the often-overlooked data preparation steps (i.e. data "scrubbing") are emphasized. READ concepts developed, including vestedness, belongingness, hierarchial cataloging of secondary courses, and maximum core-area student course determination are covered. The precise definitions of entities (e.g. "core teacher"), as used in the READ system for evaluation decisions are defined. This manual presents the details of the READ system from many perspectives, including the statistical perspective of the educational researcher, the database designer, a procedures manual for READ team members, and an introductory description of the READ system. Tutorial sections on relational databases and data warehousing are included. The proliferation of commercial data warehousing and a

proposed future READ system are presented. The READ Technical Manual is currently about 500 pages and includes nine chapters, nine appendices and a bibliography. (See Appendix for the READ Technical Manual Table of Contents.)

Conclusion

Evaluation is the process of providing information for decision making. Educational evaluation applies scientific procedures to collect and structure reliable and valid data which is statistically summarized to yield quantitative results to make decisions about educational programs of interest. A Structured Query Language (SQL) relational database warehousing system such as READ does not alter the established educational evaluation components. Rather, it provides an indispensable data pipeline from which evaluation design and statistical processing phase draws and arranges data for analyses.

The sought after objectivity in evaluation information support for decision making depends upon the scientific design and statistical procedures used to control and manage the data associated with the program being investigated. Traditional methods of reporting data from a data query or aggregation process unencumbered by scientific design and statistical control procedures yields results which are open to a variety of interpretations, alternative hypotheses, and unknown influences. While good intuition is a wonderful quality, prudent decision makers rely on evaluation results whenever available or obtainable. The READ system's inherent wealth of legacy data, data quality control procedures and data management functions greatly facilitate the school district's capabilities to yield objective decision support evaluation results.

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